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(54) Method and apparatus to improve gas dispersion and gas mass transfer in a stirred tank reactor

(57) A method and apparatus for improving mixing of liquid in a stirred tube reactor with gas contained or introduced into the head space above the liquid in the reactor. Draft tubes fixed to or an integral part of the shaft of an agitator system including a radial flow impeller rotated by the shaft used to stir the liquid extend from above the liquid to a location near the impeller so that rotation of the shaft and draft tube induces flow of gas from the head space through the tube for introduction into the liquid at or adjacent the impeller.

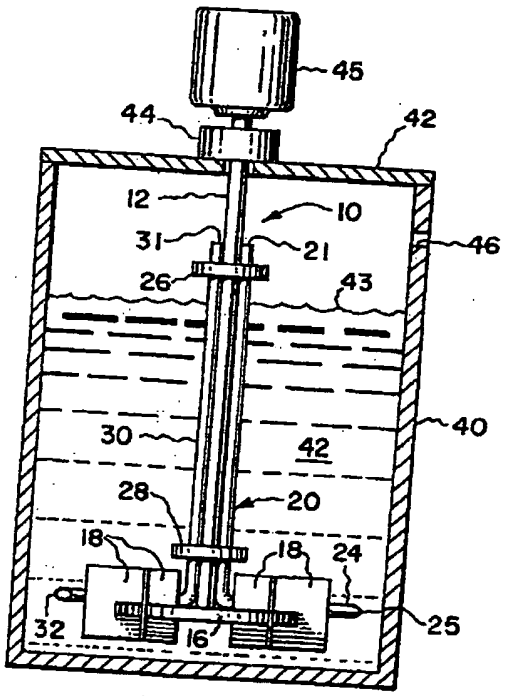

FIG. 4

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time comparing processes of the prior art and of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, a conventional turbine impeller assembly according to the present invention is shown generally as 10. The conventional turbine impeller consists of a solid impeller shaft 12 and a turbine impeller 14 generally disposed at one end of the shaft 12. Turbine impeller 14 can be configured in various ways such as shown in the drawing consisting of a bottom plate 16 and a plurality of vanes or blades 18. The impeller 14 can be mounted at the bottom of the shaft via any fastening means such as welding, bolting and the like, as is well known in the art.

According to the present invention, at least one L-shaped draft tube 20 having a vertical section 22 and a bottom or foot section 24 is fixed to the shaft by any convenient fastening devices such as collars or split mounting brackets one of which is shown as 26 in Figure 3. For ease in assuring balance of the shaft, it is convenient to have two L-shaped draft tubes 20 and 30 which are identical in size and shape mounted on diametrically opposed sides of the impeller shaft 12. As shown in Figures 2 and 3, the L-shaped draft tubes 20 and 30 are positioned using split-collars 26 and 28. The split collars or brackets 26,28 can be held with set screws or can be welded or otherwise bonded together to fix the L-shaped draft tubes 20, 30 to the impeller shaft 12. The L-shaped draft tubes are constructed so that the bottom or foot portion 24 of the L can extend outwardly in a radial direction from the shaft 12 parallel to or coextensive with the vanes 18. The discharge end 25 of bottom portion 24 of tube 20 can extend beyond the vanes 18. The discharge end 25 of bottom portion 24 L-shaped draft tube 20 can terminate in a reduced section or nozzle to control the size of the gas bubbles emanating from the tube. It is also possible to close the end of tube 25 and have a plurality of small holes along the end of foot portion 24 to introduce gas into the liquid. A preferable shape for the discharge ends 25,32 is achieved by cutting of the end of each tube at an acute angle as shown in Figure 2 so that the longer edge of the tube outlet is the leading edge as the tube rotates, the direction of rotation being shown by the curved arrow R. It is also possible to use a porous plug to close end 25 of bottom portion 24 to further disperse the gas as it exits the tube. The vertical portion 22 of tube 20 is of a length so that it projects above the liquid in the reactor as will be more fully explained below.

Referring to Figure 4, there is shown a reactor 40 having disposed therein a liquid 42. The liquid level 43 is such that there is a head space 44 above the liquid. The impeller assembly 10 is mounted in the reactor so that the impeller 14 is positioned deeply within the liquid 42. Impeller shaft 12 projects above a top 42 of vessel 40 to an optional intermediate gear box 44 which in turn is connected to a motor 45. Motor 45 is adapted to rotate shaft 12 in accord with the requirement of the gas/liquid reaction. Gas can be introduced into the head space 44 of reactor 40 through one or more ports 46 as is well known in the art.

The motor and gear arrangement 44, 45 can be any system conventionally used with a stirred tank type reactor.

L-shaped tubes 20 and 30 are positioned so that the discharge or bottom end 25, 32 of the tubes are in the liquid. A first or entry end 21, 31 of tubes 20, 30 respectively, projects above the level of the liquid 43. In view of the fact the tubes 20, 30 are fixed to the impeller shaft 12, as the impeller shaft 12 rotates, gas contained in the head space 44 is drawn into the entry ends 21, 31 of tubes 20, 30 and is forced outwardly through the discharge ends 25, 32 to intimately mix with the liquid which is put in motion by the radially vanes 18 of the impeller 14.

Use of the L-shaped draft tubes according to the present invention facilitates rapid and inexpensive retrofitting of an existing turbine impeller in a stirred tank reactor to promote intimate mixing of a gas and a liquid.

In order to achieve gas flow through the L-shape tubes, the Froude number must exceed 0.2 which is determined by the following equation:

$$\frac{N^2L^2}{gH} > 0.2$$

- N = rotation rate (rotation/time)
- L = 2x the length of tube from center of agitator rotation axis to gas outlet
- g = gravitational constant
- H = height of liquid above L-shaped tube outlet

Increasing the rotation rate increases the pressure drop and gas is drawn down the tubes and into the liquid at the impeller where it is dispersed. The length of the gas outlet end of the L-shaped tube can be lengthened or shortened to modify the Froude number and alter the gas pumping performance (to match existing agitator rotation rate).

As stated above, the method and apparatus of the invention can be changed by modifying the submerged outlet of the L-shaped tubes. For example, a sintered metal cap can be added to improve bubble formation. Tapers or restrictions can also be added to modify flow and gas induction as well as the use of a capped outlet and a plurality of holes in the outlet tube. The method and apparatus of the present invention will not put a burden on agitated power requirements. In point of fact, adding a dispersed gas phase at the impeller will actually decrease the agitated power requirements.

In order to illustrate the effectiveness of the present invention, a 1.8 liter high pressure type 316 stainless steel reactor (Metler RC 1 reactor calorimeter) was filled with 900 grams of isopropanol and 100 grams of nitrobenzene. The mixture was heated to 120 °C and

clamps.

11. An agitator according to claim 1 wherein said L-shaped tube is bonded to said shaft at one or more locations along a vertical portion of the L-shape.

12. An agitator according to claim 11 wherein said bonding is by an adhesive.

13. An agitator according to claim 11 wherein said bonding is by welding.

14. An agitator according to claim 1 wherein said vertical portion of said L-shaped tube is formed as an integral part of said shaft and a horizontal portion of said L-shaped tube is a tube fixed at right angles in fluid tight relation to said vertical portion.

15. A method for increasing the effectiveness of dispersion of a gas contained in a head space above the liquid contained in a stirred tank reactor having an impeller containing an agitator on a shaft adapted to impart motion to said liquid comprising the steps of:

installing at least one generally L-shaped tube having a bottom section terminating in an orifice end and a vertical section terminating in an entry end disposed at right angles to one another on said shaft with said bottom portion of said generally L-shaped tube disposed to extend proximate a peripheral edge of said agitator and said vertical section of said L-shaped tube fixed to said shaft and projecting above said liquid; and

rotating said shaft and said L-shaped tube at a speed sufficient to induce flow of gas from said head space through said entry end and out said orifice end of said L-shaped tube.

16. A method according to claim 15 wherein said shaft is rotated at a speed to satisfy the relationship:

$$\frac{N^2L^2}{gH} > 0.2$$

wherein N= rotation rate, L = 2x the length of said L-shaped tube from a point at a center of rotation of said agitator to said outlet orifice, g = gravitational constant and H = height of liquid above the outlet orifice of said L-shaped tube.

17. An agitator for use in a stirred tube reactor used to mix a liquid contained in said reactor with gases introduced into a head space above said liquid in said reactor comprising a generally cylindrical shaft adapted to extend along a vertical axis of said reactor, said shaft having a first end with a radial flow impeller adapted to be disposed in said liquid and a second end projecting above said liquid into said head space of said reactor, said shaft adapted to be rotated whereby said impeller imparts motion to said liquid;

a closed cylindrical passage in said shaft extending from a location proximate said first end of said shaft to a location proximate said second end of said shaft above said liquid;

at least one inlet passage having an axis disposed at a generally right angle to said shaft said inlet passage communicating with said cylindrical passage and aid head space in said reactor; and

at least one outlet passage having an axis disposed at a generally right angle to said shaft said outlet passage communicating with said elongated passage and said liquid proximate said impeller.

18. An agitator according to claim 16 wherein said agitator has a plurality of inlet and outlet passages.

19. An agitator according to claim 16 wherein said outlet passage contains a gas permeable member.

20. An agitator according to claim 18 wherein said gas permeable member is a porous plug.

21. An agitator according to claim 15 wherein said outlet passage contains a tube or nozzle extending along said impeller.

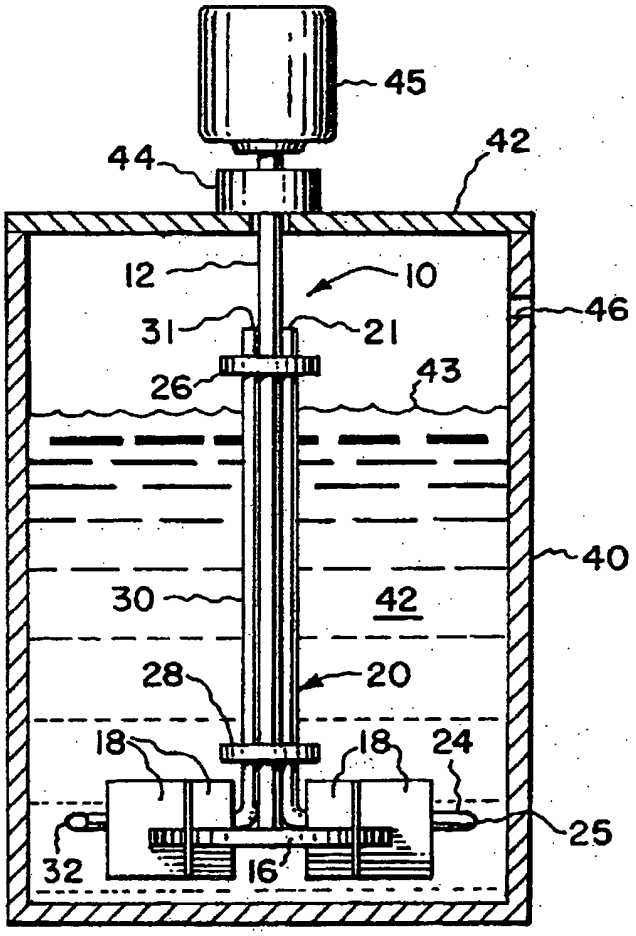

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 96 11 1448

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE-U-92 01 820 (G.KIRSCHEMANN) * claims; figure 1 *	1-21	B01F3/04 B01F15/00 B01J19/18
A	EP-A-0 516 921 (STELZER RÜHRTECHNIK) * claims; figures *	1-21	
A	DE-A-25 44 204 (BAYER AG) * claims; figures *	1-14,16	
A	US-A-5 160 459 (CL.GUARNASCHELLI ET AL) * claims; figures *	1,17	
A	DE-A-29 33 784 (SUMA) * claims; figure 2 *	1,17	
A	EP-A-0 403 091 (IMPERIAL CHEMICAL INDUSTRIES) * figure 2 *	1,17	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
B01F
B01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	29 October 1996	Cordero Alvarez, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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